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The effect of size and shape of targets upon the near lateral phoria and duction measurements

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Abstract

The problem was to determine the effect of size and shape of targets upon the near lateral phoria and duction measurements.

Degree Type

Thesis

Degree Name

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Subject Categories

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THE EFFECT OF SIZE AND SHAPE OF TARGETS UPON THE NEAR LATERAL PHORIA AND DUCTION MEASUREMENTS

A Thesis

Presented To The Faculty Of

The College Of Optometry

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In Partial Fulfillment

Of The Requirements For The Degree

Doctor Of Optometry

by

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Problem

The problem was to determine the effect of size and shape of targets[1] upon the near lateral phoria and duction measurements.

[1] An interim report.

Procedure

To determine the effect of size and shape of targets upon the near lateral phoria and duction measurements two experiments were conducted in which different shaped targets were used.

In the first experiment square targets were used and measurements were taken on four students of Pacific University. The set of targets used consisted of five squares ranging in equal log steps from 1 square millimeter to 10,000 square millimeters. They were designated in the following manner: target #1, 1 mm^2; target #2, 10 mm^2; target #3, 100 mm^2; target #4, 1,000 mm^2; and target #5, 10,000 mm^2. The targets were made of black art paper on a background of white drawing paper.

An attempt was made to select a group of subjects with near lateral phoria and duction measurements, taken under clinic conditions of testing, which would be within the range of expecteds as compiled by Morgan[2]. These subjects were selected by examining clinic records on file at the Pacific University Optometry Clinic.

The Bausch & Lomb Green's refractor was used because the Risley rotary prisms had a total range of 60 prism diopters.

The illumination was kept constant at 40 foot candles by using a 75 watt bulb at a distance of 18½ inches from the target. The target was kept at a constant distance of 16 inches from the subject. Holes were punched in the targets so that they could be hung onto the cardholder with small pins to avoid the interference of the dark lines of the cardholder.

The testing sequence was 13A(near phoria), 16A(positive relative convergence), 16B break and recovery(positive fusional reserve), 17A(negative relative convergence), and 17B break and recovery (negative fusional reserve).

[2]Morgan, M. W. The Clinical Aspects of Accommodation and Convergence. Am. J. Optom. & Arch. Am. Optom. August, 1944.

The targets were presented in a random sequence* which was prepared in advance. Each square target was shown to each subject a total of twenty times, and the same sequence was used for each subject.

Ten series of measurements were taken at each sitting with at least one hour elapsing between each sitting. A series of measurements consisted of 13A, 16A, 16B, 17A, and 17B.

The tests were conducted in the following manner:

The near phoria (13A) was taken with the dissociating prism placed over the left eye enough to completely seperate the targets vertically. The measuring prism was placed over the right eye, and the reading was taken by turning this prism from excessive base in to the position where the subject reported that the targets were aligned vertically.

For the base out to blur (16A) measurement the rotary prisms were placed at zero and moved in a base out direction until the subject reported a definite blur. If no blur was reported, this finding was recorded as an X.

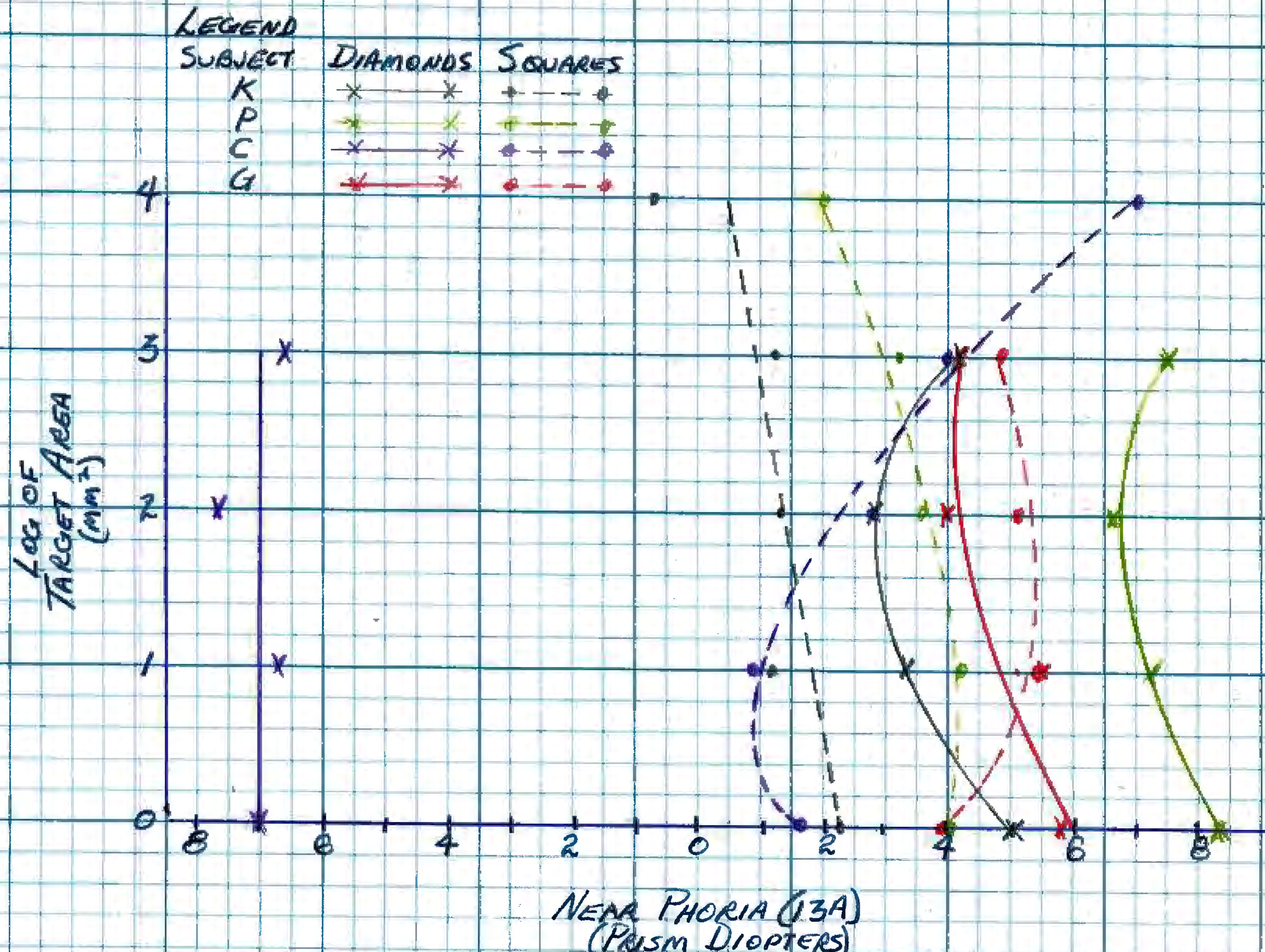
The 16B break finding was obtained by continuing to rotate the prisms in a base out direction until the subject reported a break. The prisms were then turned more base out to obtain a definite seperation and then rotated base in until the subject reported a recovery. This was recorded as the 16B recovery finding.

The base in to blur (17A) finding was obtained in a similar manner to the 16A finding except that the prisms were turned in a base in direction until the subject reported a definite blur.

The 17B break and recovery points were obtained in a similar manner to the 16B break and recovery findings except that the prisms were turned in a base in direction until the subject reported a break and in a base out direction to a subsequent recovery.

*See Appendix

The date and time were recorded for each sitting. All tests were taken with the habitual near prescription of the subject in the phoropter.



LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF TARGET AREA (MM²)
0
1
2
3
4
8
6
4
2
0
2
4
6
8
NEAR PHORIA (13A) (PRISM DIOPTERS)

GRAPH #1

Results

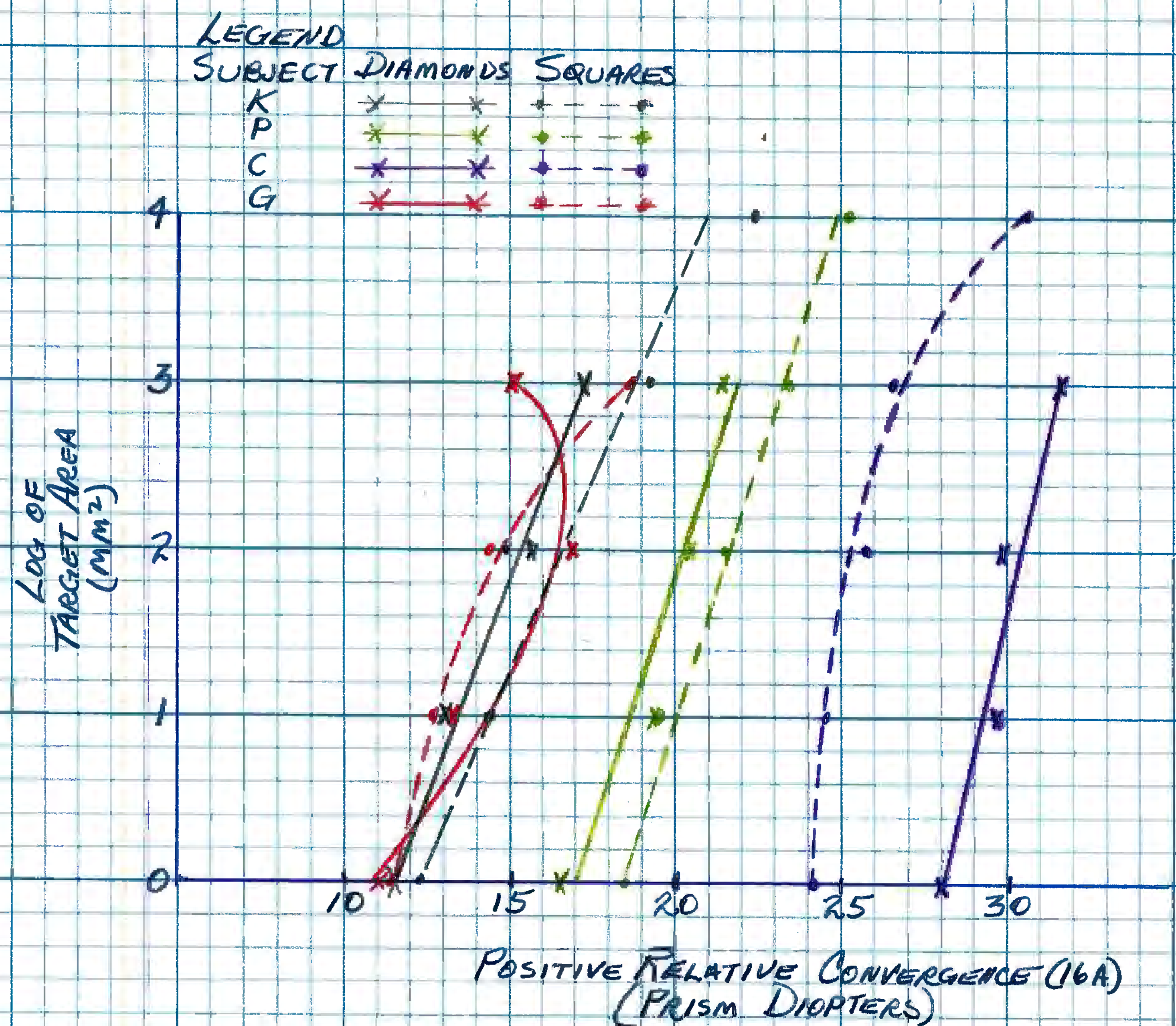
The data obtained from this experiment were included in the appendix as data sheets numbers 1 - 7. The graphs compiled from this data were placed as near as possible to the description of the results obtained from them.

Data sheets #1 through #4 showed the sums, means, standard deviations, and the range of the findings of each test on each size of target for the squares and diamonds for subjects Peterson, Kowallis, Christensen, and Grundison respectively. Each of these data sheets was marked with the first initial of the surname of that subject. In the following discussion and in the graphs the subjects will be referred to in this manner.

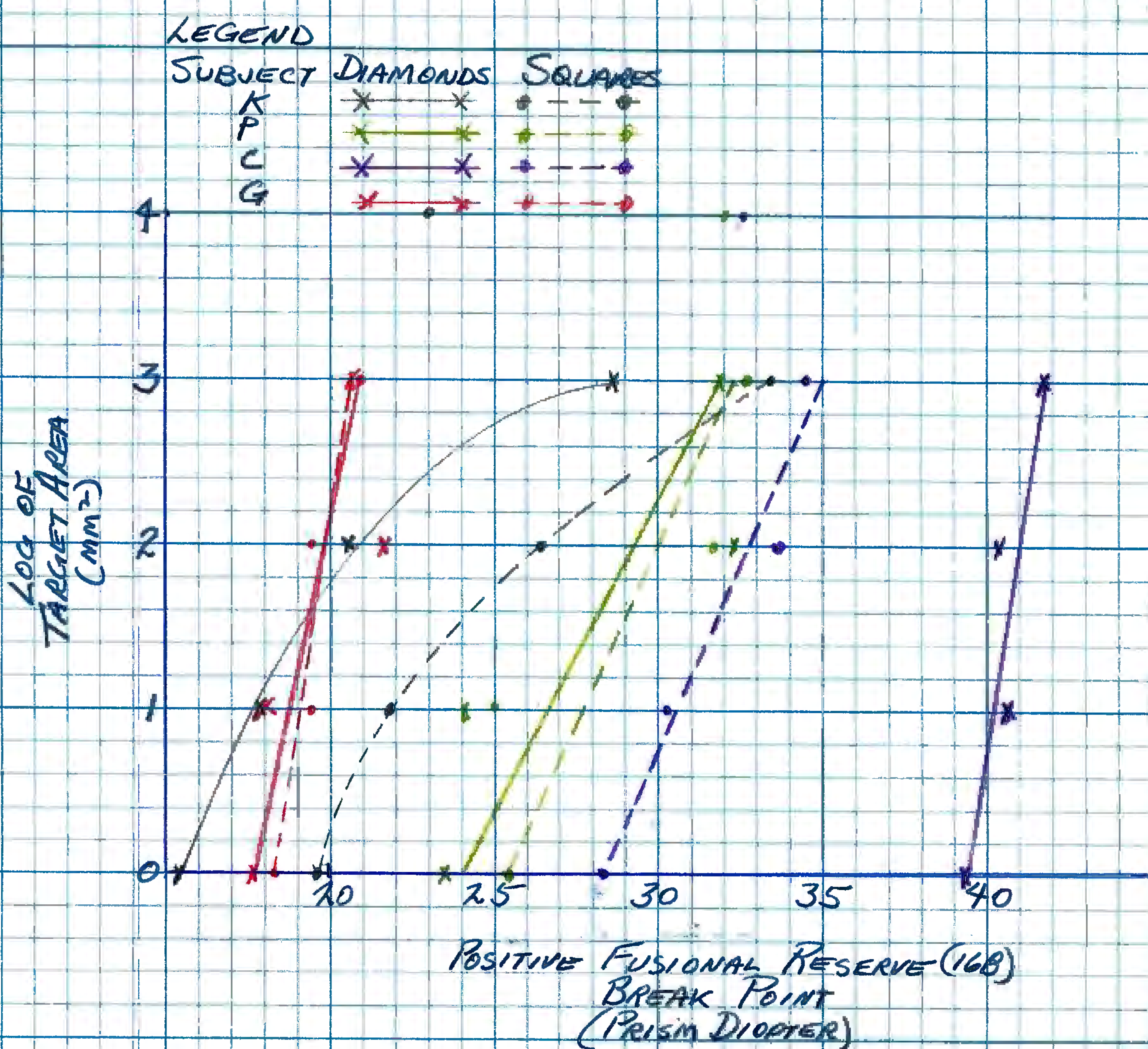
Data sheet #6 indicated the average change in prism diopters for each increase in target size for all subjects for all tests. The means for each test for all subjects are also given as well as the individual means for the series of tests. The following data sheet (#7) indicated the slopes of the best fit lines for all subjects.

The ordinate of each graph represented the log of the target size in square millimeters. The abscissa of graph #1 represented the near lateral phoria in prism diopters. Along the abscissa of graphs #2 through #7 are plotted the near lateral duction findings in the order in which they were taken for all four subjects. The abscissa of graphs #8 through #15 represented the near lateral ductions for each individual subject. The even numbered graphs denoted the base out ductions, and the odd numbered ones indicated the base in duction findings.

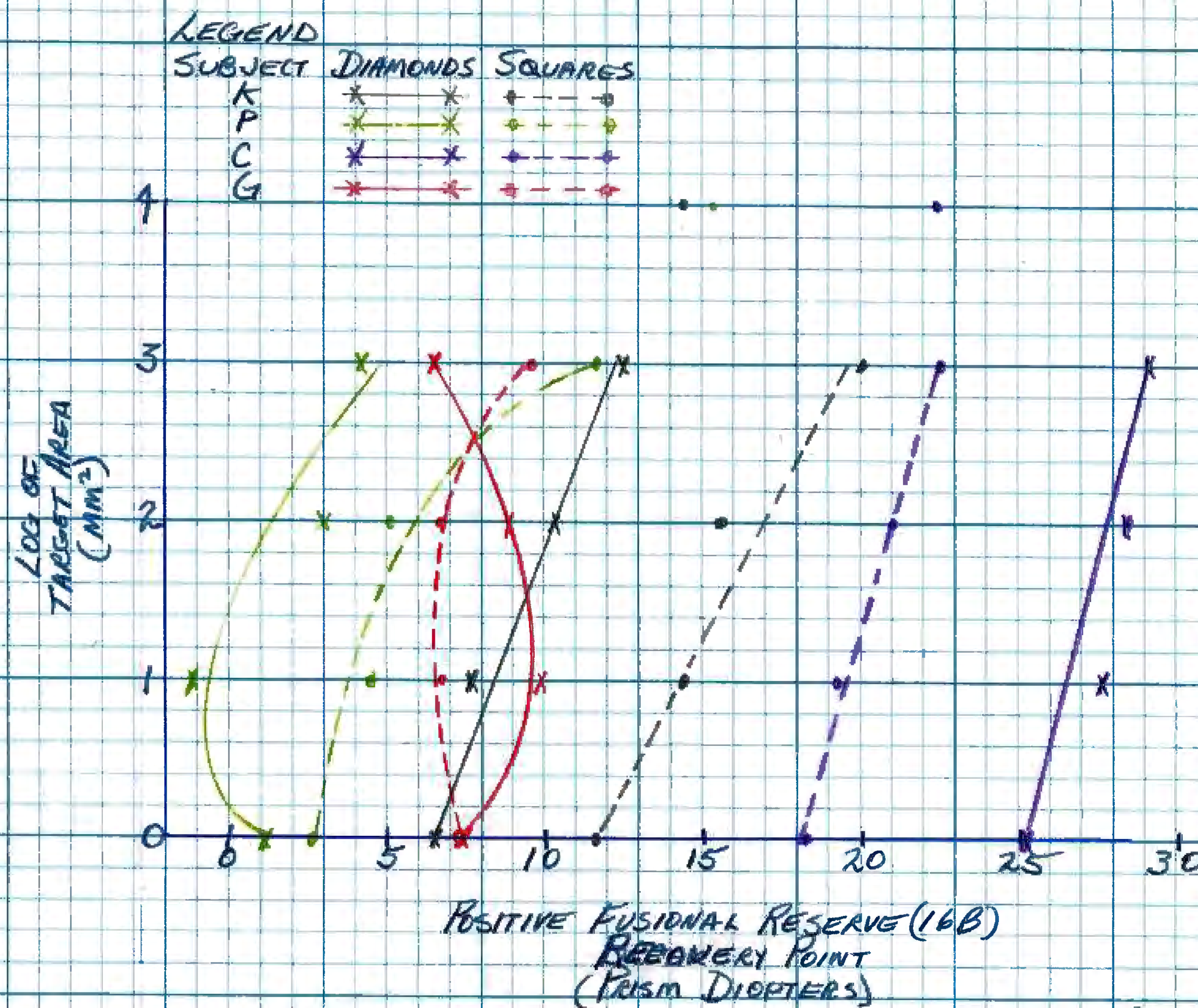
Graph #1 showed the relationship of the near lateral phoria to the target size for all subjects. This graph indicated that for the square targets, subjects "P" and "G" showed an increase in exophoria from the smallest to the next larger target and a gradual decrease with each succeeding target. The best fit line to the findings of subject "K" showed a gradual linear decrease in exophoria with each increase in target area.


LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF TARGET AREA (MM²)
0
1
2
3
4
10
15
20
25
30
POSITIVE RELATIVE CONVERGENCE (16A) (PRISM DIOPTERS)

GRAPH #2

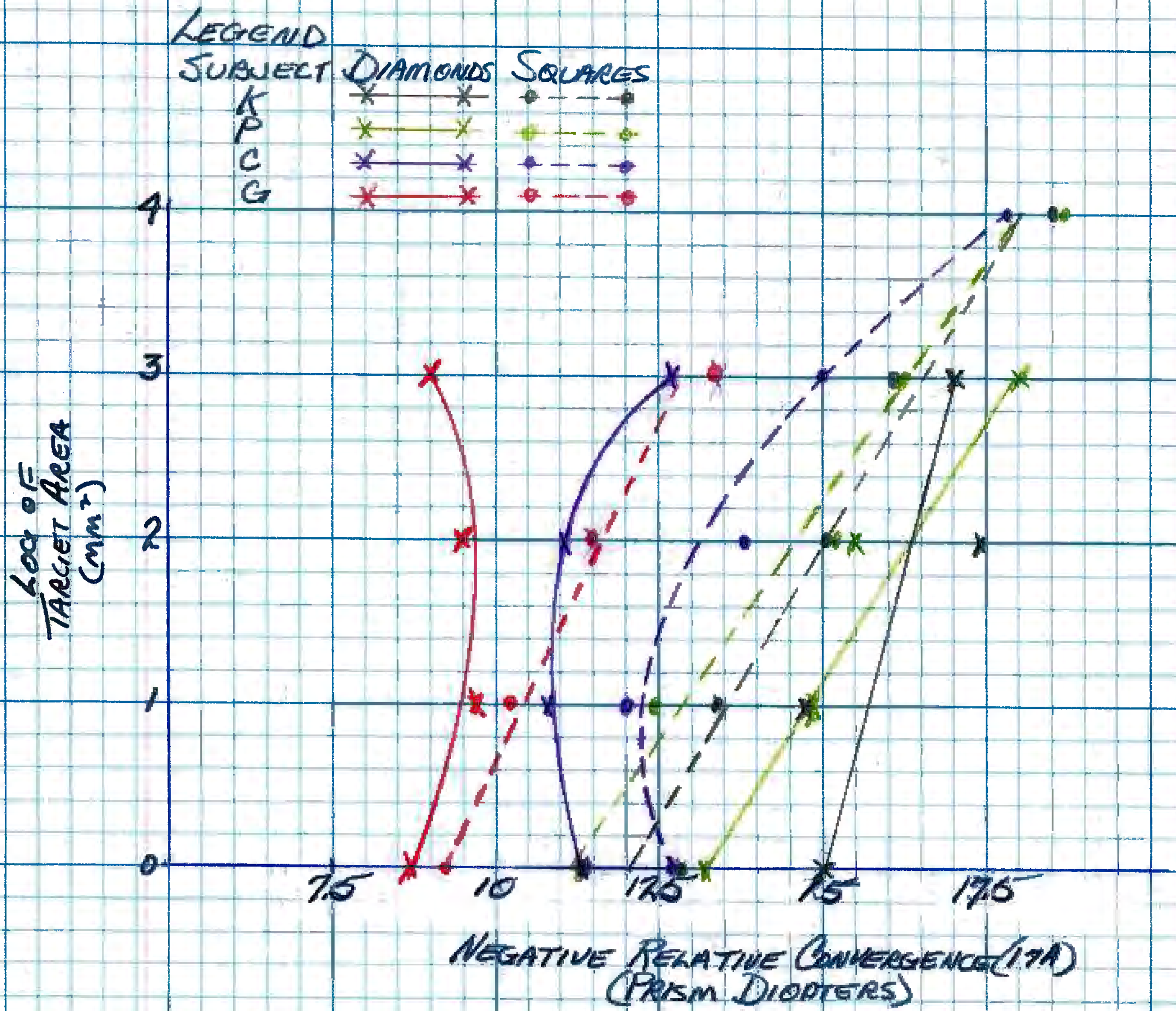

LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF TARGET AREA (MM²)
0
1
2
3
4
20
25
30
35
40
POSITIVE FUSIONAL RESERVE (16B) BREAK POINT (PRISM DIOPTER)

GRAPH #3



LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF TARGET AREA (MM²)
0
1
2
3
4
0
5
10
15
20
25
30
POSITIVE FUSIONAL RESERVE (16B)
RECOVERY POINT
(PRISM DIOPTERS)

GRAPH #4


LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF
TARGET AREA
(mm²)
0
1
2
3
4
7.5
10
12.5
15
17.5
NEGATIVE RELATIVE CONVERGENCE (17A)
(PRISM DIOPTERS)

GRAPH #5

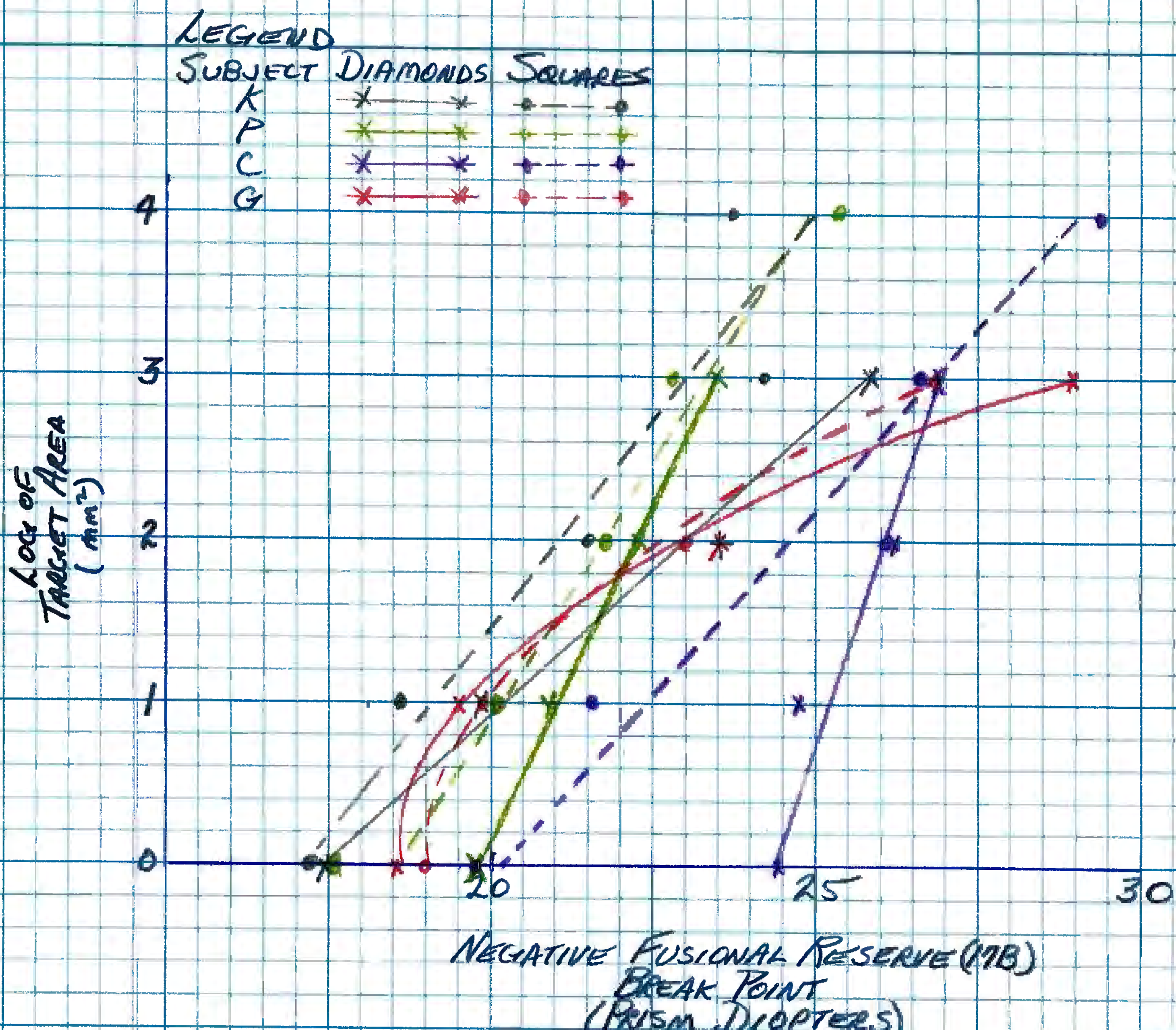
The findings of subject "C" exhibited an inverse relationship to those of subjects "P" and "G" in that a decrease in exophoria was displayed between targets #1 and #2, followed by a gradual increase in exophoria with each subsequently larger target.

Graph #2 showed the relationship of the positive relative convergence (16A) to target size a d shape. This graph indicated that when using the square targets the positive relative convergence of each subject increased as the target area became greater. The approximate slopes of the lines for each subject indicated only a small amount of variation, being 0.51 for subject "K", 0.64 for subject "P", 0.61 for subject "C", and 0.41 for subject "G".

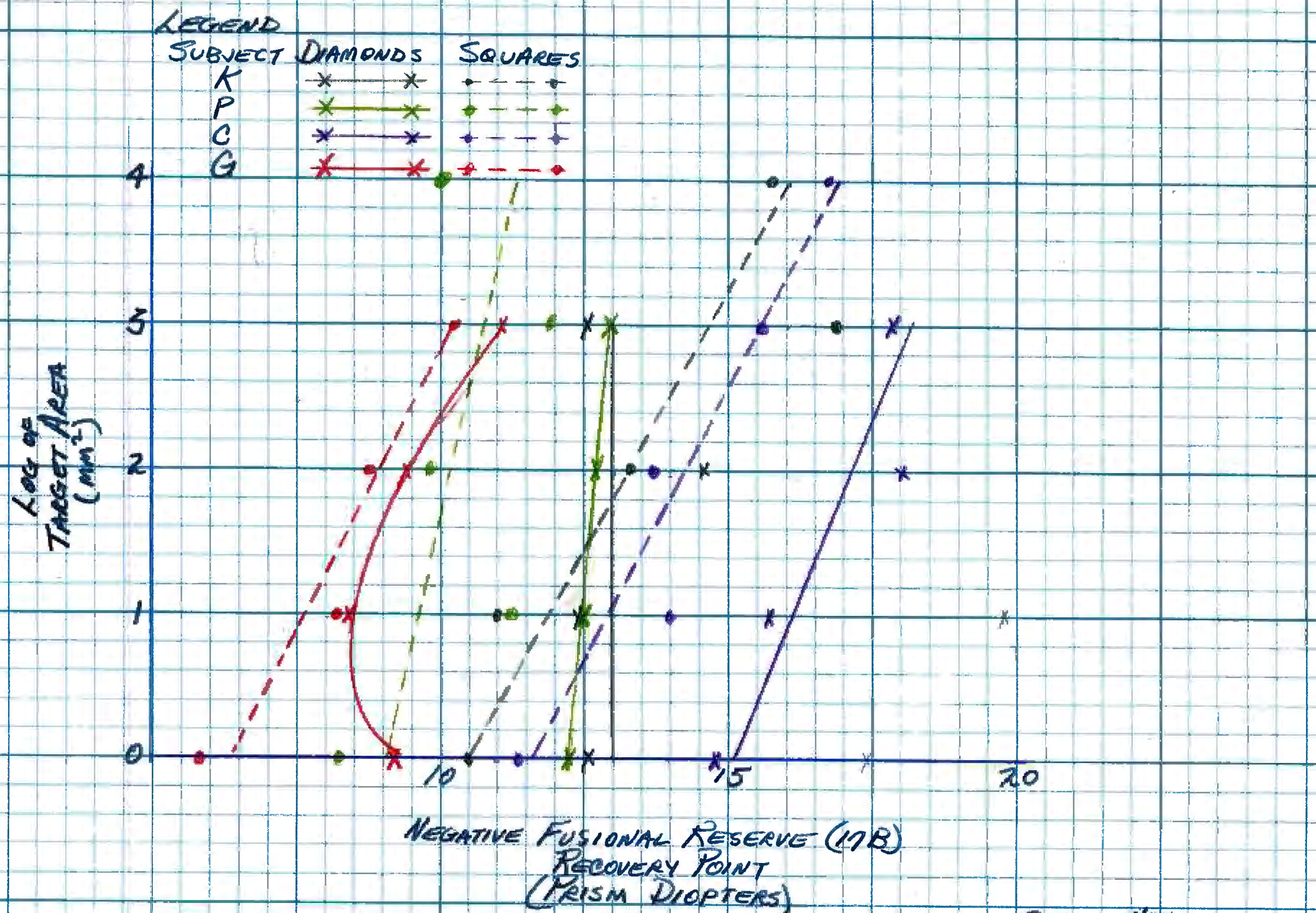
Graph #3 presented the relationship of the break point of the positive fusional reserve (16B) to the target size and shape for all subjects. Each subject as indicated by the graph showed a larger break finding for each succeeding larger square target with only two exceptions. Subject "G" showed no change in the finding between the #2 and #3 targets, while subject "P" exhibited a decrease between targets #1 and #2. The slopes of the lines of each subject for this finding were: subject "P", 0.41; subject "K", 0.22; subject "C", 0.44; and subject "G", 0.41.

Graph #4 represented the relationship of the recovery points of the positive fusional reserve (16B) to the target size and shape for all subjects. Using the square targets, the recovery points became larger with each increase in target area for all subjects except subject "G". This subject showed a decrease in the duction finding for targets #2 and #3 and an increase with the #4 target. The slopes of the lines for subjects "K" and "C" were 0.40 and 0.68 respectively. The findings of the other two subjects were best represented by a curve.

Graph #5 illustrates the change in negative relative convergence (17A) for each change in target area. When using the square targets, subjects "K", "P", and "G" demonstrated an increase in the negative relative convergence for each increase in target size, the slopes of their lines being 0.73, 0.62, and


LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF TARGET AREA (mm²)
0
1
2
3
4
20
25
30
NEGATIVE FUSIONAL RESERVE (MB) BREAK POINT (PRISM DIOPTERS)

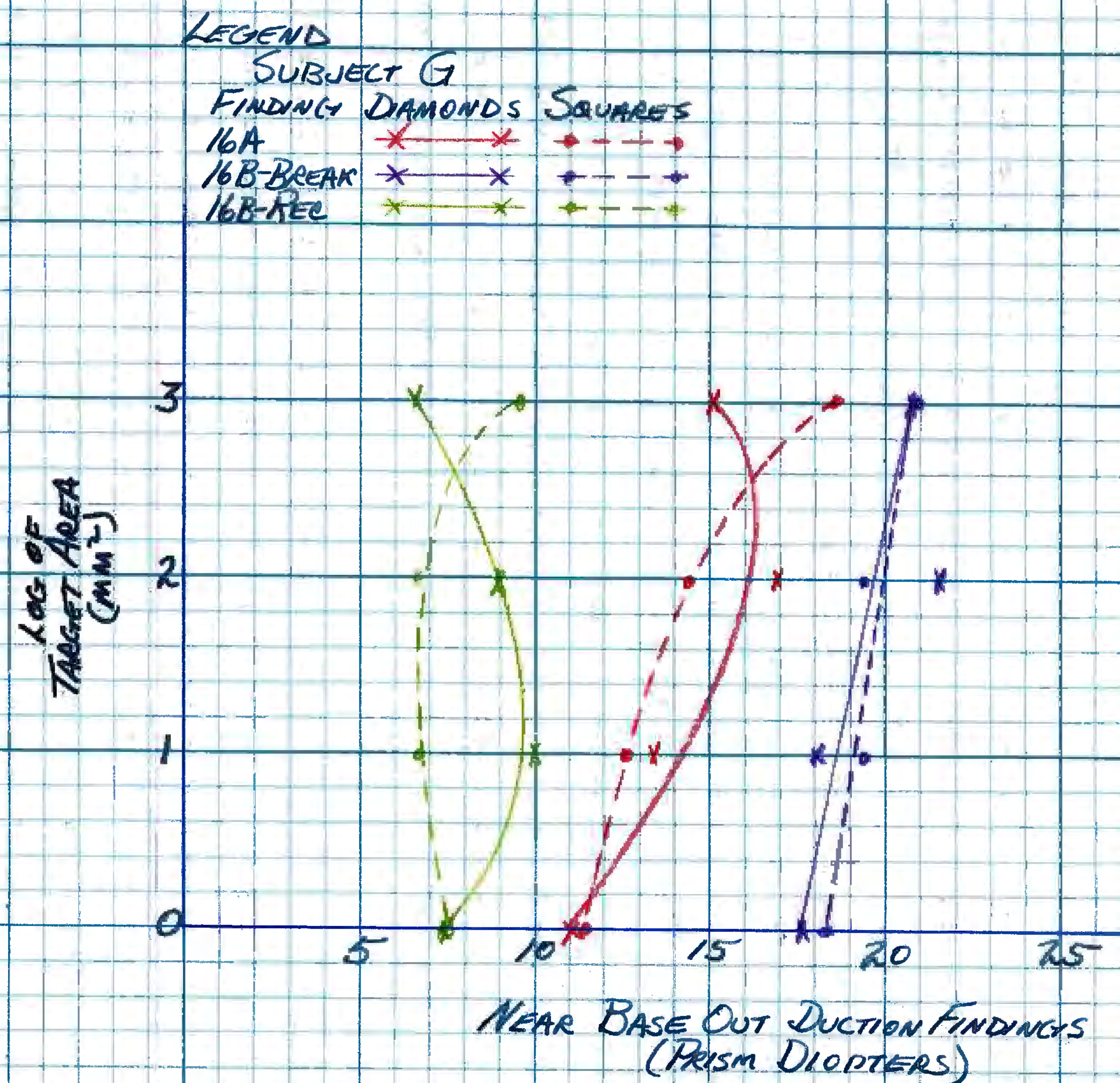
GRAPH #6



LEGEND
SUBJECT DIAMONDS SQUARES
K
P
C
G
LOG OF TARGET AREA (MM²)
0
1
2
3
4
10
15
20
NEGATIVE FUSIONAL RESERVE (17B) RECOVERY POINT (PRISM DIOPTERS)

GRAPH #7

-π-



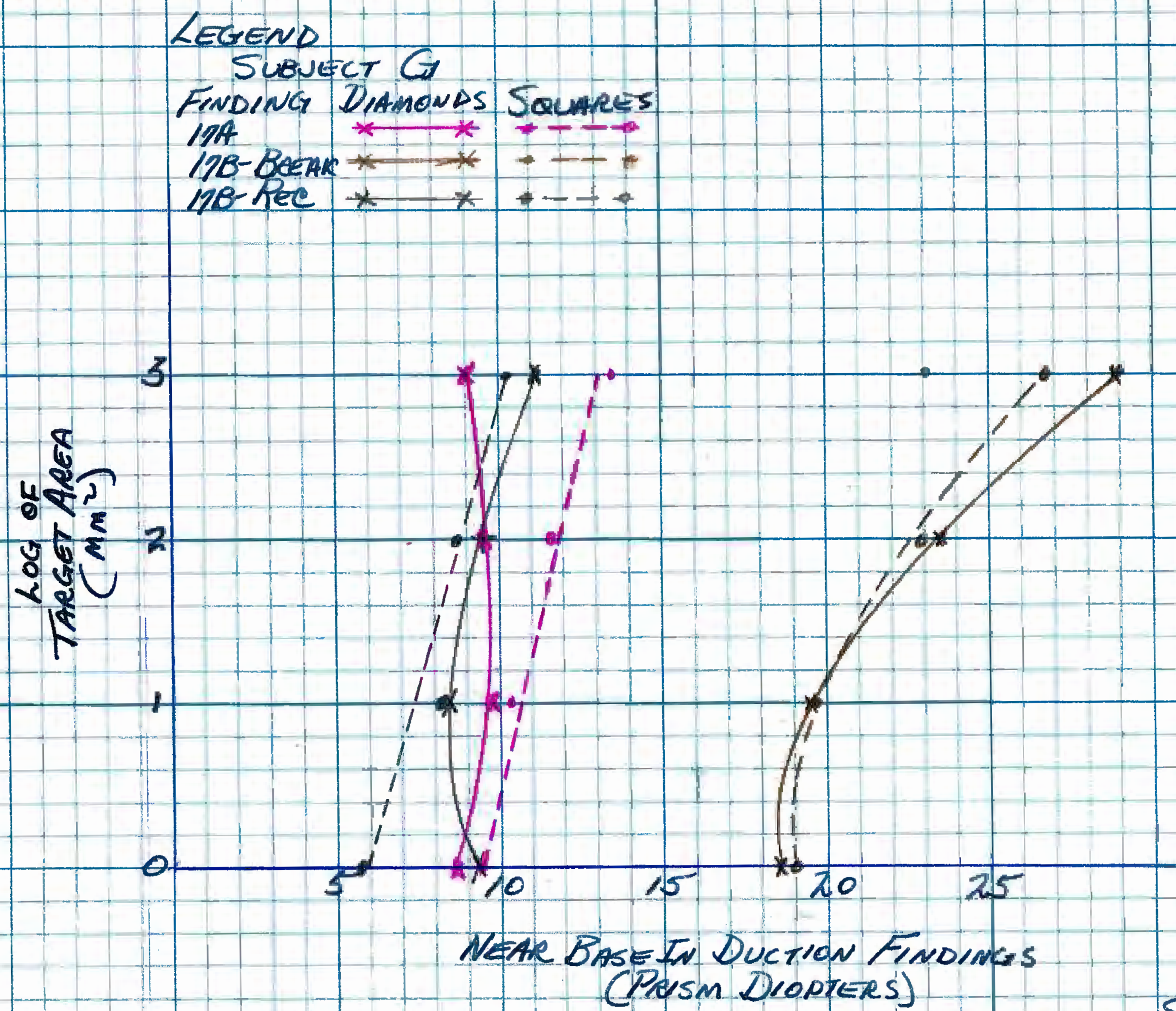
SUBJECT G
GRAPH #8

0.81 respectively. The negative relative convergence decreased for subject "C" between targets #1 and #2 and increased markedly thereafter.

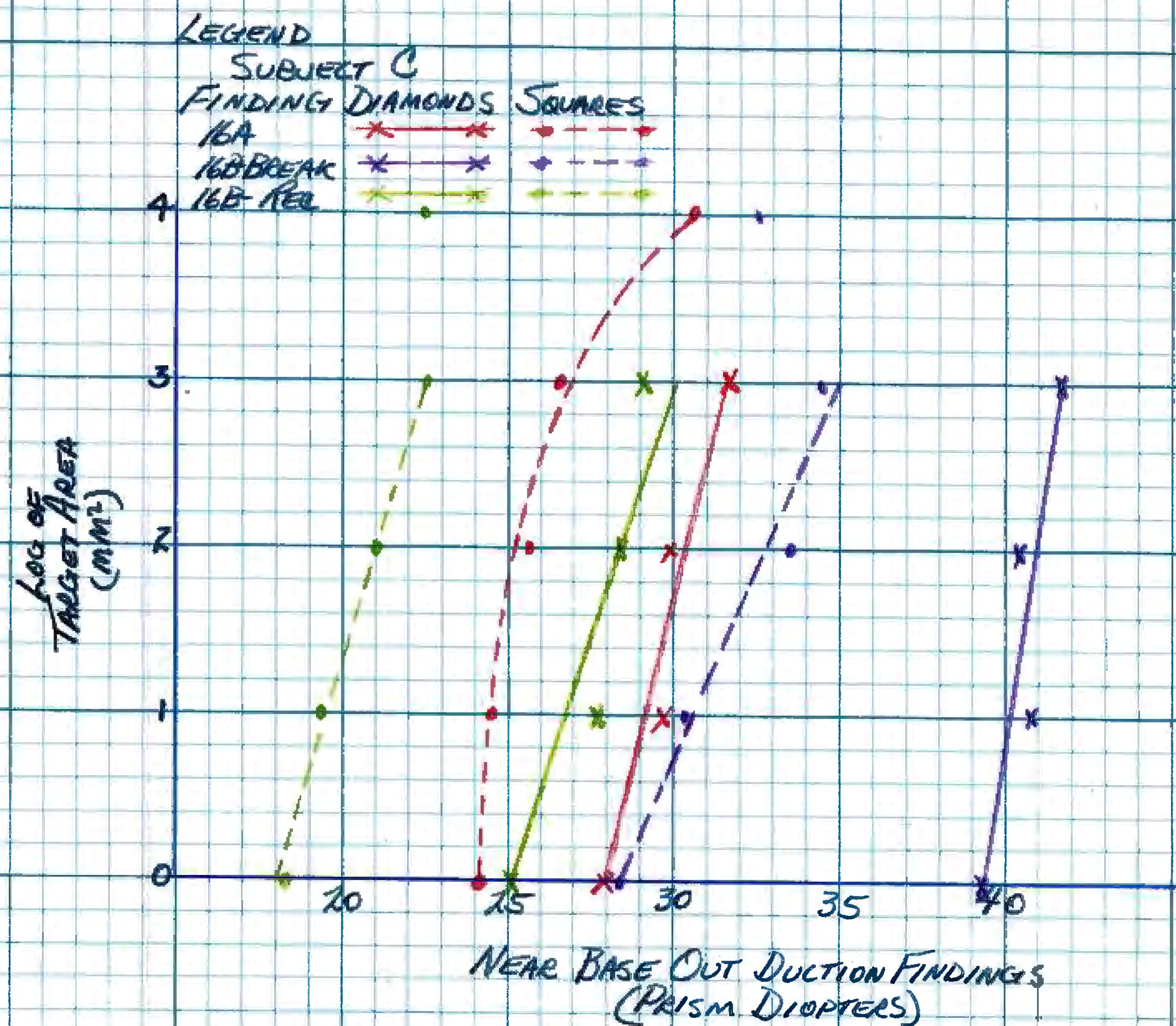
Graph #6 showed the relationship between the negative fusional reserve breakpoint and the target area for all subjects. The square targets produced an increase on the 17B break point for each increase in target area with only one exception; this being the largest target used on subject "K". Subject "G" had findings which differed from the fairly linear relationship of the other subjects in that the increase was small between the #1 and #2 targets while the increase brought about by targets #3 and #4 was larger than the similar findings of the other subjects. The slopes of the lines were as follows: subject "K", 0.51; subject "P", 0.59; subject "C", 0.42; and the findings of subject "G" were best fit by a curve so no slope was determined.

Graph #7 illustrates the relationship of the negative fusional reserve recovery point for all subjects to the size and shape of the test target. Using the square targets, all subjects exhibited a general increase in the recovery points as the area of the target was increased. The findings of subject "G" showed the most consistant increase for this particular test. All of the other subjects manifested rather variable findings. The approximate slopes of the best fit lines were: subject "K", 0.55; "P", 2.0; "C", 0.86; and "G", 0.68.

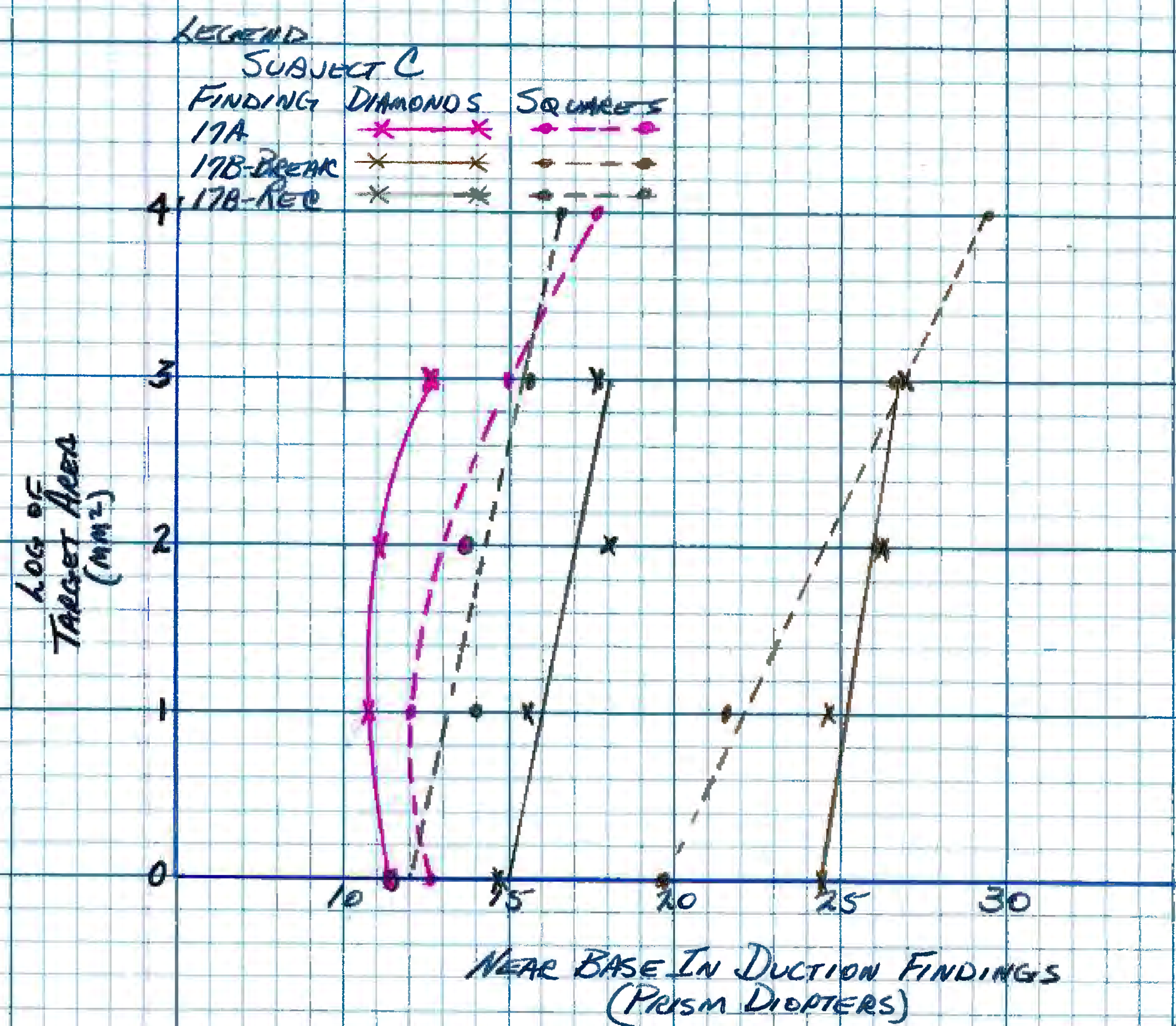
Graph #8 demonstrated the relationship of the near base out duction findings to the target size and shape for subject "C". When using the square targets, each increase in target size brought about a corresponding increased blur finding. The break points also exhibited a general increase, although not as great as the blur findings. The recovery findings exhibited a decrease for targets #2 and #3, and an increase for #4. The average change in prism diopters per change in target area was as follows: 16A, 2.5 prism diopters; 16B-break, 0.8 prism diopters; and for 16B-recovery, 0.7 prism diopters.



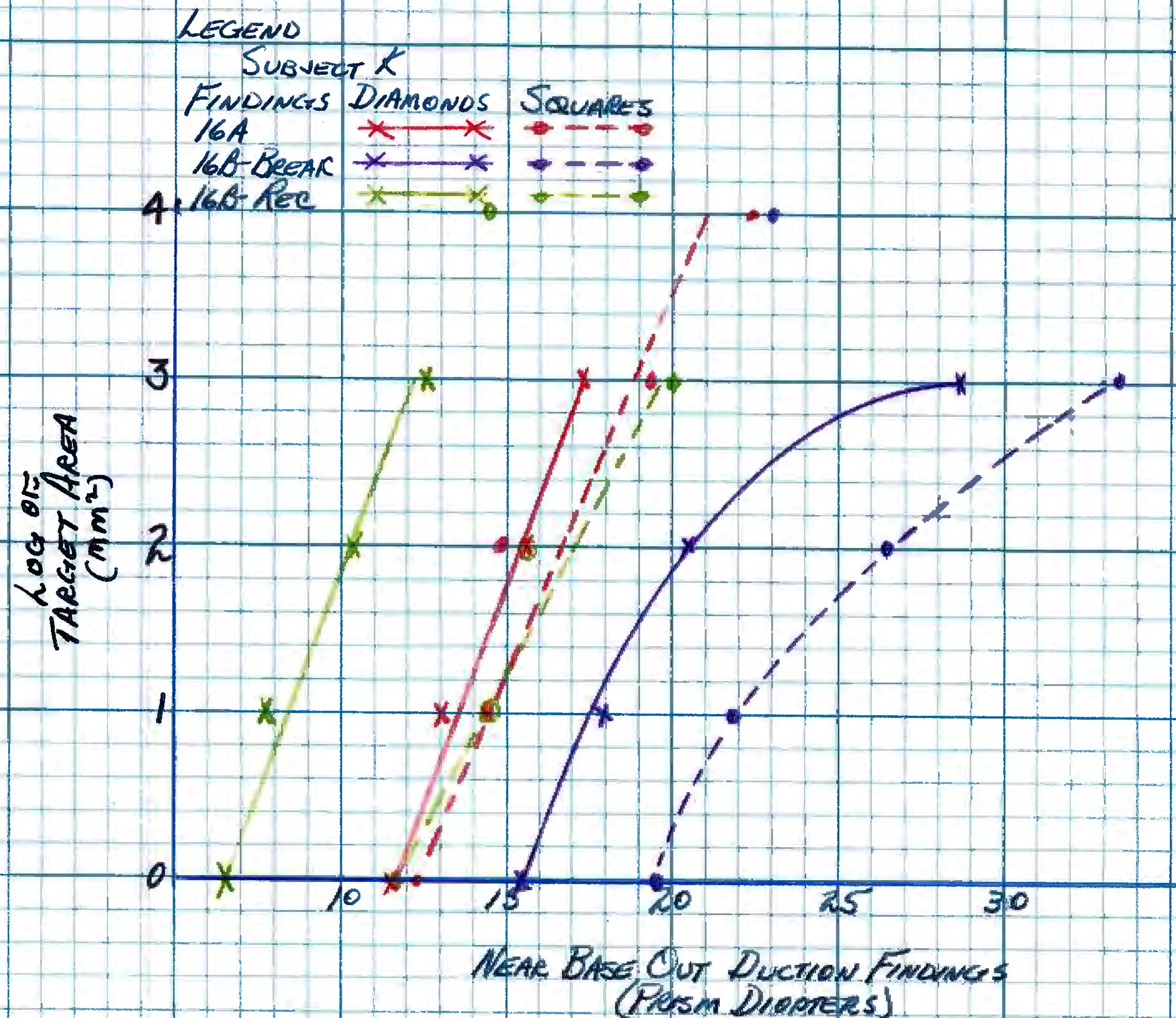
SUBJECT G
GRAPH #9



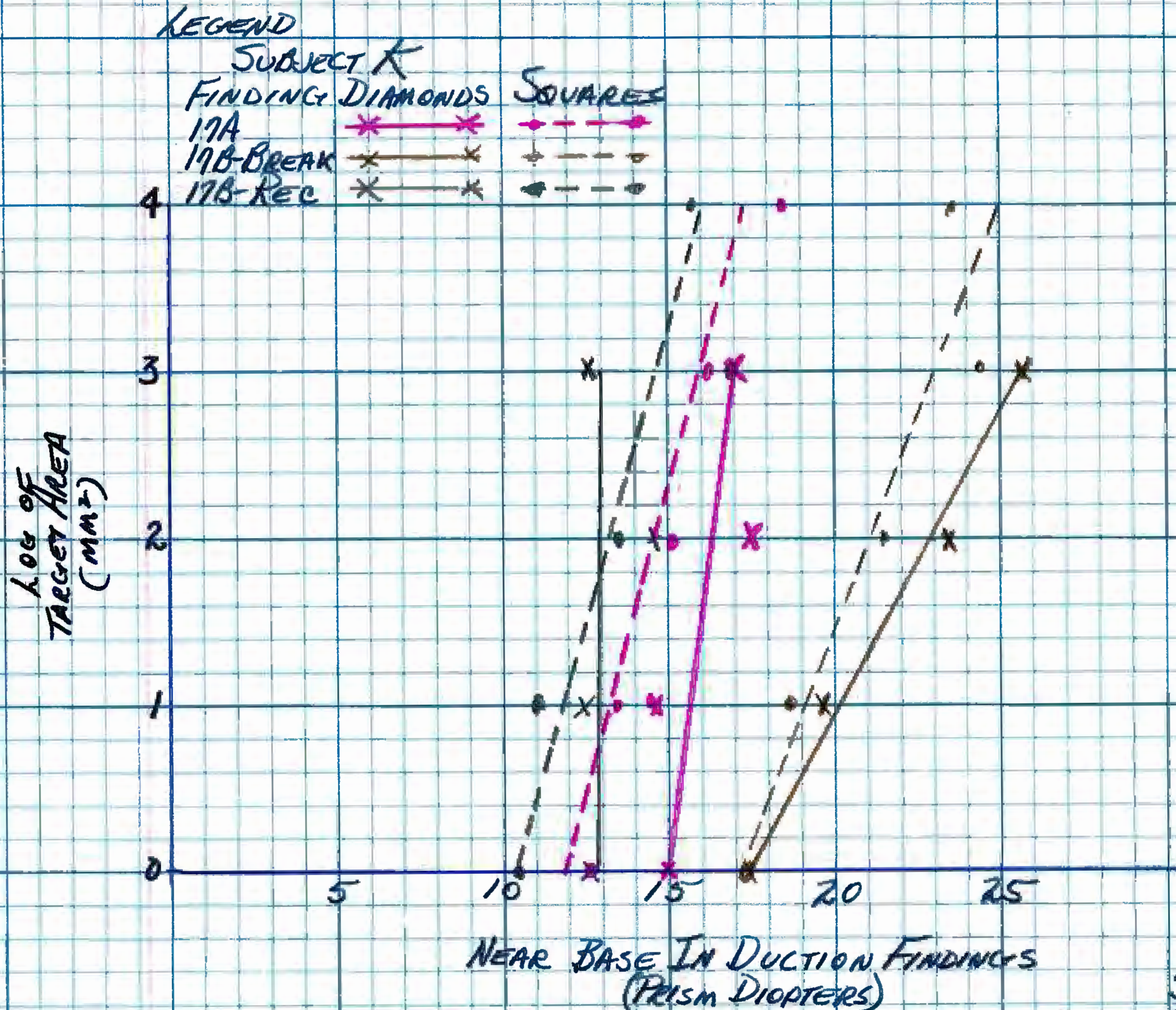
SUBJECT C
GRAPH #10



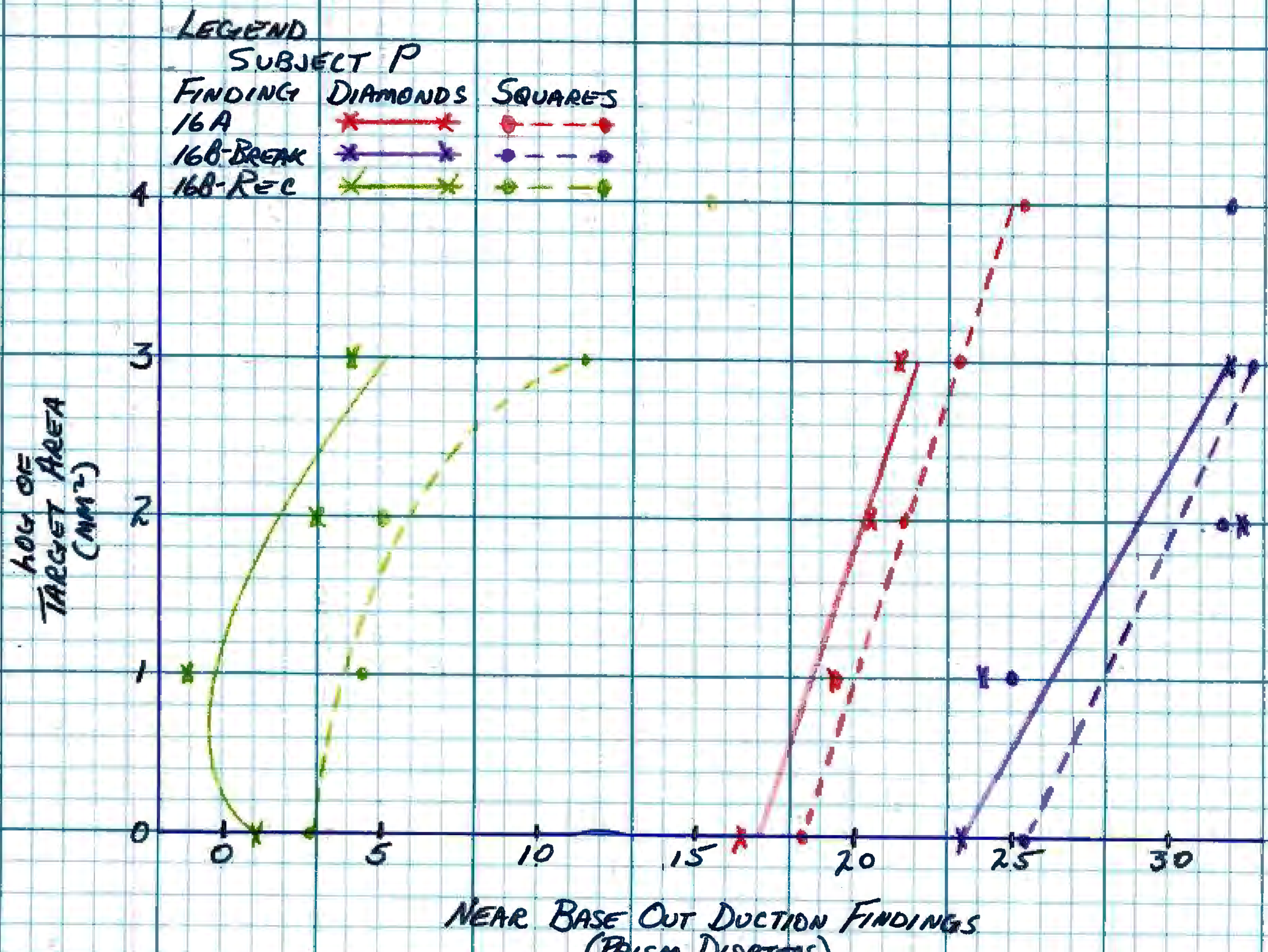
SUBJECT C
GRAPH #11



SUBJECT K
GRAPH #12



SUBJECT K
GRAPH #13



Subject P
Graph #14

Graph #9 displayed the relationship of the near base in duction findings of subject G to the target size and shape. The graph revealed that for each change in target size the ductions were increased in the following average amounts: 17A, 1.2; 17B-break, 2.6; and 17B-recovery, 1.5 prism diopters.

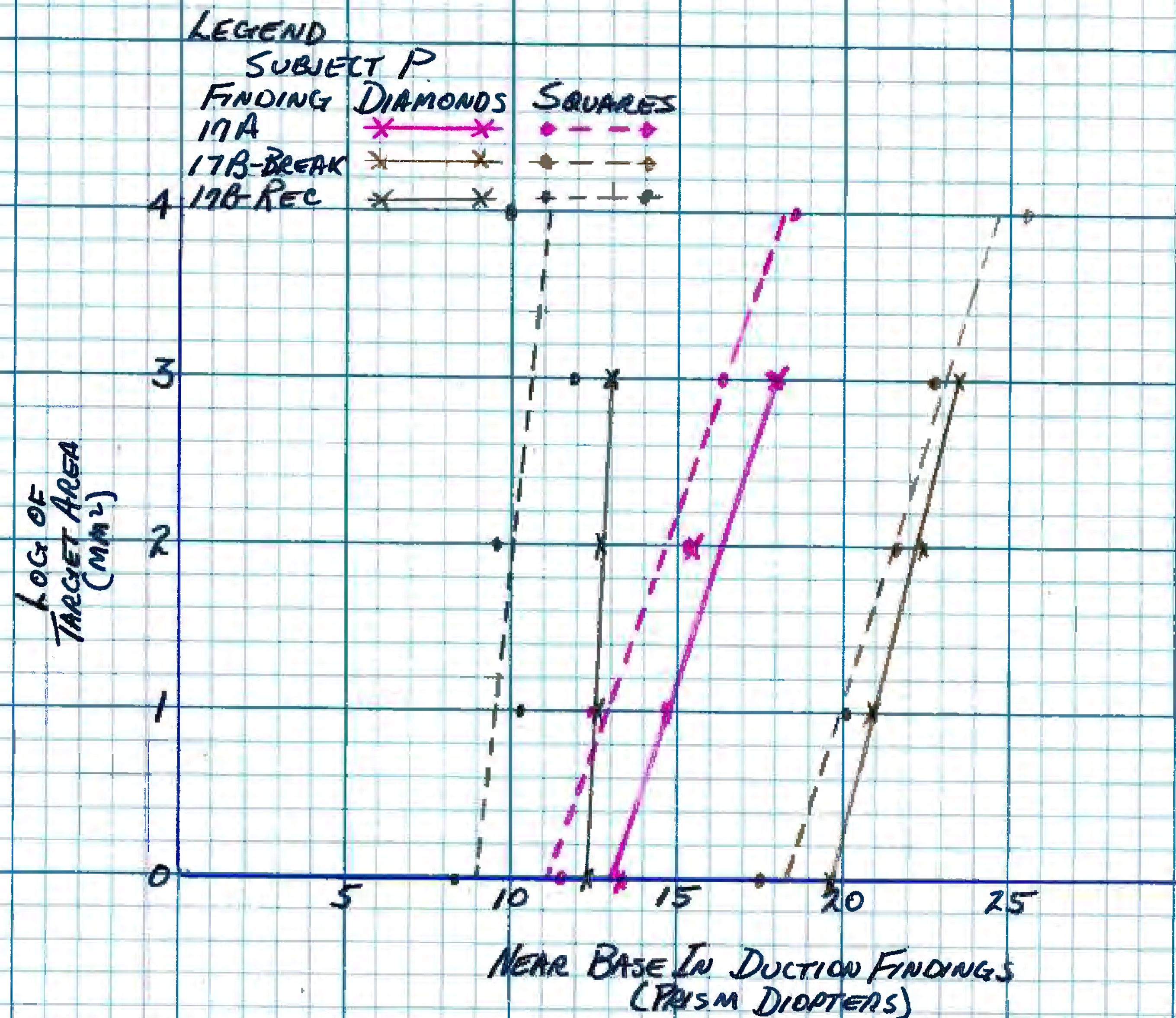
Graph #10 showed the relationship of the near base out ductions to target size and shape for subject "C". This graph indicated that as the targets became greater there was a general increase in all of the base out ductions. The changes in prism diopters per change in target area were as follows: 16A, 1.7; 16B-break, 2.3; and 16B-recovery 1.5 prism diopters.

Graph #11 demonstrated the effect of target size and shape upon the near base in duction findings for subject "C". This graph indicated that as the target size became greater, the break and recovery increased also, in what can best be described as a linear relationship. For the base in to blur findings the #2 target brought about a smaller reading than the #1 target with each succeeding target increasing in magnitude. The average increase for each increase in target size was as follows: 17A, 1.3; 17B-break, 2.4; and 17B-recovery, 1.2 prism diopters.

Graph #12 disclosed the relationship of the base out findings of subject "K" to the size and shape of the target. All findings manifested an increase in the ductions with each increase in target size. The average magnitudes were as follows: 16A, 2.0; 16B-break, 4.6; and 16B-recovery, 2.5 prism diopters.

Graph #13 demonstrated the change in the base in findings for subject "K" with various changes in target size and shape. There was a general increase in all findings for an increase in target size. These are the average increases: 17A, 1.4; 17B-break, 2.0; and 17B-recovery 1.8 prism diopters.

Graph #14 revealed the relationship of the near base out ductions to the target size and shape for subject "P". It showed that as the targets became larger the various base out duction findings tended to increase in a direct linear relationship. The magnitude of these increases are as follows: 16A,



SUBJECT P
GRAPH #15

1.6; 16B-break; 2.4; and 16B-recovery, 2.8 prism diopters.

Graph #15 presented the relationship of the near base in duction findings to the target size and shape for subject "P". All of the square target findings, except the 17Brecoveries, exhibited an increase in magnitude as the targets became progressively larger. The 17B recovery findings, however, demonstrated alternate increases and decreases with the largest target being greater by 1.8 prism diopters than the reading of the smallest target. The following average increases in the ductions for each change in target size were evidenced: 17A, 1.6; 17B-break, 1.7; 17B-recovery 0.5 prism diopters.

Procedure

In order to determine the effect of shape upon the near lateral phoria and duction measurements a second experiment was undertaken. As before measurements were taken on four students of Pacific University. The targets which were used consisted of four diamonds ranging in equal log steps from 1 square millimeter to 1,000 square millimeters. They were designated as follows: target #1, 1mm^2; target #2, 10 mm^2; target #3, 100 mm^2; and target #4, 1,000 mm^2. The targets were made by turning a square target 45° in the frontal plane.

Ten observations of each diamond target were made instead of twenty as was done with the square targets. These observations were taken in a prepared random order[4] which was the same for all subjects.

The apparatus used and the method of testing remained the same as for the experiment of the squares except in the instances mentioned above.

To conclude the experiment ten series of measurements were taken using the reduced Snellen near point card as the target. These measurements were used to represent a standard for each subject under clinical testing conditions.

[4] Ibid.

Results

For comparison the data and graphs obtained from this experiment were combined with those found in the experiment using squares for targets. Their description and location has therefore been previously explained.[5]

Data sheet #5, found in the appendix, represents the sums, means, standard deviations, and the range of the findings for each test on the standard measurements for each subject.

Graph #1 shows the relationship of the near lateral phoria to the target size and shape for all subjects. For the diamond targets the curves for subjects "K", "P", and "G" are similar, indicating some decrease in exophoria for each of the three smaller targets and an increase in exophoria for the largest target in each case. For subject "C" this line indicates no definite change in phoria for change in target size.

Graph #2 shows the relationship of the positive relative convergence (16A) to target size and shape. This graph indicates that all findings increased when using the diamond targets with only one exception. This exception was the #4 target for subject "G", which decreased about 2 prism diopters. The slopes of the lines representing the diamond targets for subjects "K", "P", and "C" were 0.53, 0.68, and 0.81 respectively. No slope was determined for the graph representing the diamonds for subject "G" since these data were fit best to a curve.

Graph #3 displays the relationship of the break point of the positive fusional reserve finding (148) to the target size and shape for each subject. With the diamond targets each subject indicates a general increase in the ductions with the use of larger targets. The exceptions to this were these: Subjects "G" and "P" presented smaller findings for target #4 than for target #3, while subject "C" evidenced a slight decrease in going from the #2 to the #3 target. The slopes for subjects "K", "P", "C", and "G" were as follows: 0.23, 0.36, 1.2, and 1.3 respectively.

[5] Chapter III Results (Squares)

Graph #4 exhibits the relationship of the recovery of the positive fusional reserve to the target size and shape for all subjects. Subjects "K" and "C" show an increase in the recovery points for every increase in the size of the diamond targets. The slopes were 0.51 and 0.61 respectively. The findings of subject "P" evidenced a decrease from the #1 to the #2 target with subsequent increases for the other targets, while subject "G" presented the reverse situation. No slopes were derived for these findings since they were best fitted by curved lines.

Graph #5 indicates the change in negative relative convergence (17A) for each change in target size for both diamonds and squares for all subjects. In considering the diamonds it was found that subject "P" was the only one who had a consistant increase in the blur points for each increase in target size; the slope of the line was 0.63. In general, the negative relative convergence increased for subject "K" between targets #1 and #4 and the slope was 1.5. Subjects "C" and "G" presented an inverse relationship with one another. The former showed a decrease in the negative relative convergence between targets #1 and #2 with an increase from the #2 to the #3 target which became more pronounced between the #3 and the #4 targets while subject "G" showed the opposite pattern.

Graph #6 shows the relationship between the negative fusional reserve findings and the target size for all subjects. The diamond findings exhibit an increase in the ductions for every increase in target size. The findings of subject "G" evidenced a slight increase between targets #1 and #2 and increased greatly between #'s 2, 3, and 4 thus varying from the linear arrangement of the other subjects. The slopes of the lines are as follows for subjects "K", "P", and "C": 0.32, 0.79, and 1.2.

Graph #7 denotes the relationship between the negative fusional reserve recovery points and the size and shape of the test targets for all subjects.

With the diamond targets it was found that subject "P" showed a consistant increase for each increase in target size although it was very small. Subject "K" showed no significant change in the recovery point with changing size of the target, except for the #3 target which showed an increase of two prism diopters. For subject "C" there was an increase for all targets except the #4 which was slightly less than the #3 target. Subject "G" exhibited a decrease between the #1 and the #2 targets and an increase for all subsequent targets. The slopes of the lines are as follows: "K", infinity; "C", 1.0; "P", 3.8; and that for "G" was not calculated since the best fit line was a curve.

Graph #8 demonstrates the relationship of the near base out duction findings to target size and shape for subject "G". When the diamond targets were used an increase in the target size was evidenced in about half of the findings. For the blur and break findings the first three targets brought about a greater finding for each, while the largest target resulted in a decrease in each case. For the recovery findings only the second target produced a measurement larger than the preceding one, and all subsequent measurements were progressively less. The average changes per target are: 1.3 prism diopters for 16A, 0.8 prism diopters for 16B-break, and -0.3 prism diopters for 16B-recovery.

Graph #9 displays the relationship of the near base in duction findings of subject "G" to the target size and shape. With the diamond targets the graph reveals an increase in the 17B-break findings for each increase in target size. For the negative relative convergence finding the only increase occurred with the #2 target. The two largest targets each brought about a smaller finding than the previous one. The line representing the data of the recovery points indicated that the reverse of the preceding was true with only target #2 producing a smaller recovery point than the previous target. The average increase in duction findings for an increase in target size are: 17A 0.1; 17B-break 3.5; and 17 B-recovery 0.6 prism diopters.

linear relationship. The magnitude of the increase in duction findings for an increase in target size are: 16A 1.5 prism diopters, 16B-break 2.8 prism diopters, and 16B-recovery 1.0 prism diopters.

Graph #15 presents the relationship of the near base in duction findings to the target size and shape for subject "P". All findings demonstrate a continued increase in magnitude as the targets become progressively larger. The magnitudes were as follows: 17A 1.9 prism diopters, 17B-break 1.3 prism diopters, and 17B-recovery 0.3 prism diopters.

Discussion Of Results

For the near lateral phoria, 13A, three of the subjects, "K", "G", and "P", showed a slight decrease in exophoria for each increase in target size, while subject "C" evidenced either no change or an increase in exophoria. The means of subject "C" exhibit a marked esophoria for all of the diamond targets and as exophoria for all of the square targets. This change from exophoria to esophoria first appeared during the sixth sitting for the square targets and became more pronounced as the experiment progressed. The diamond targets, used following the square targets, produced no exophoric findings. None of the other findings of subject "C" changed appreciably, thus indicating a possible change in the set of fixation at that time, although the subject remembered no such change.

An increase in the target size brought about a general increase in the ductions for all individuals. Of 210 total possibilities there were only 27 instances which displayed a decrease in the mean of the duction findings with an increase of the target size. To show a quantitative relationship between the findings of the square and diamond targets the change in prism diopters per log unit change of target was determined. In calculating this change the following formula was used:

$$\frac{N_2 - N_1}{Y_2 - Y_1}$$

N_2 and N_1 represent the points of greatest and least magnitude respectively on the best fit straight line, and Y_2 and Y_1 represent the largest and smallest targets used respectively. These calculations indicate that squares showed a mean increase for all subjects of 1.9 prism diopters per log unit of area while the diamonds showed a mean increase for all subjects of 1.4 prism diopters per log unit of area. Each subject showed approximately the same amount of change with the diamonds having the smaller change in each case. For subject "K", the change was 0.4 prism diopters per log unit; subject "P", 0.3 prism diopters per log unit; subject "C" 0.7 prism diopters per log unit; and subject "G", 0.6 prism diopters per log unit.

Practice effect was a factor that was not compensated for between the taking of the findings for the square and the diamond targets since all of the findings were taken on the square targets first. For this reason a direct comparison of the magnitudes in the measurements due to the target shape may be invalid. These following very interesting observations were made since they seem to indicate certain individual trends. The relationship between the square and diamond targets for subjects "P" and "K" was phenomenally similar. In the base out ductions the square targets showed the greatest magnitude, while for the base in ductions the diamond targets showed the greatest magnitude for both of these subjects. Subject "C" disclosed the reverse of the above for the base out ductions and concurred with the above for the base in findings except for the 17A square findings which were greater in magnitude. The findings of subject "G" were inconclusive in this regard, since the findings for the squares and diamonds failed to parallel one another as well as those for other subjects. Subject "G" was a pre-optometry student and more naive as to optometric testing than were the other three subjects which may account for some of the variability of this subject.

In commenting about the standard deviations for the data there were certain trends present. The excessively high standard deviations of subject "G" for the square 13A tests were explained previously. Subject "K" showed no appreciable difference for these findings between the shape of the targets and the direction in which the ductions were taken. Subjects "P" and "C" had standard deviations which were generally higher for the square targets than for the diamonds. In turn "C" and "G" manifested generally larger standard deviations for the base out findings that nor the base in findings.

The slopes of the lines were calculated from the best fit lines of the data except where a curve fitted the findings best. If the straight line passed thru the points for the smallest and largest targets, these were used, otherwise they were found by interpolation from the graph. The prism diopter was the unit on the abscissa while on the ordinate the log of the target area in square millimeters was used in determining the slopes.

In a previous study of this nature conducted at Pacific University[6] the targets were small circles whose size varied over a limited range. Since the results were inconclusive over such a small range it was decided to select targets which ranged in area in equal log steps from 1 square millimeter to 10,000 square millimeters. This was undertaken in order to determine the relationship between the near lateral ductions and phorias over a greater range of target size. Under testing conditions, it was found that the largest target, 10,000 square millimeters, was obstructed by the housing of the phoropter during the 16B break and recovery tests. For the above reason this target was not used on subject "G", nor was a similar sized diamond target used for any of the subjects. Because of the unsatisfactory nature of the 16b break and recovery measurements these findings were not used in plotting the graphs; however the other findings were proved satisfactory and were taken into consideration.

Due to the type of paper used in the construction of the test targets, texture was present in both figure and ground. This was noticed during the experiment and could be a variable to consider in future experiments.

As previously stated subjects were chosen whose near lateral phorias and ductions were within the range of expecteds as compiled by Morgan[7]. Several persons who were willing to act as subjects were rejected when a review of their case findings revealed that their near lateral phoria and duction findings were markedly distorted from these expecteds.

[6]Samuel Orbital, Charles Weber, and Leon Gordon; Thesis Spring 1953, Pacific University Library.

[7]Morgan, op. cit., p. 2

Others whose findings were within the expected range were unable to act as subjects because of personal reasons. Because of these factors the number of subjects was limited. The purpose for selecting subjects whose measurements were close to these norms was to see what might be expected from the "normal".

Condlusion

Due to the individual variability and the possible practice effect, no definite conclusion can be made from this experiment as to the effect of shape upon the magnitude of the near lateral phoria and duction measurements.

The amount of change in prism diopters per log unit change in target area was substantially greater for the square targets than for the diamonds.

An increase in the target size showed a slight decrease in the phoria findings for three of the subjects, but considerable individual variability was present.

An increase in the size of the target showed an increase in the magnitude of a great majority of the duction findings.

Summary

The problem was to find how the near lateral phoria and duction measurements were affected when the size and shape of the targets were varied. Two experiments were prepared and performed using first square targets which varied in size, and then diamond targets which varied in area in similar amounts to the squares. It was found that as the target size increased from one square millimeter to ten thousand square millimeters in area the lateral ductions increased and the lateral phorias showed a slight decrease. The affect of changing the shape of the targets was uncertain, but it was indicated that the average change of the duction measurements per change of the target size was larger for the squares.

Appendix

[3]The random sequence was selected by drawing lots in the following manner:

The numbers were written on pieces of paper and mixed up in a box. They were then drawn out one at a time and each number was marked in this order to form the random sequence. The order which resulted is listed below in the sequence for each sitting:

Where five targets were used:

Sitting No.	1	2	3	4	5	6	7	8	9	10
Target #	2	4	4	4	5	1	5	1	1	4
	5	1	3	4	3	1	2	5	5	3
	2	3	4	2	1	3	2	3	4	1
	5	4	4	5	4	1	3	3	2	4
	4	4	4	3	2	5	2	5	5	5
	5	3	5	5	1	1	1	5	3	2
	2	4	2	4	3	3	2	5	1	3
	1	4	1	2	5	2	1	3	2	3
	2	2	3	2	1	5	2	5	4	4
	3	1	3	1	4	1	1	5	3	2

Where four targets were used:

Sitting No.	1	2	3	4
Target #	2	4	3	3
	2	2	1	4
	4	1	3	2
	2	2	2	4
	1	4	1	3
	2	3	3	4
	3	4	1	2
	4	2	3	4
	1	3	1	4
	3	1	1	1

		Squares:			Range:		Diamonds:			Range:	
Test	Target	Sum	Mean	Sigma	High	Low	Sum	Mean	Sigma	High	Low
13A	1	79/20	4.0	1.4	7	1	83/10	8.3	1.0	10	7
	2	84/20	4.2	1.4	8	1	72/10	7.2	1.0	9	6
	3	72/20	3.6	1.2	6	2	66/10	6.6	1.0	8	5
	4	65/20	3.2	1.8	7	2	75/10	7.5	1.0	9	6
	5	40/20	2.0	1.5	6	-1					
16A	1	370/20	18.5	3.1	24	14	116/7	16.6	2.7	22	13
	2	310/16	19.4	2.8	24	15	174/9	19.3	2.0	23	16
	3	433/20	21.6	4.4	29	16	205/10	20.5	4.3	28	13
	4	348/15	23.3	3.5	28	14	193/9	21.4	3.2	26	17
	5	429/17	25.2	3.5	32	19					
16B-B	1	508/20	25.4	3.5	37	20	235/10	23.5	1.8	27	21
	2	501/20	25.0	3.6	33	20	241/10	24.1	3.1	28	19
	3	637/20	31.8	4.0	40	23	323/10	32.3	4.0	36	24
	4	654/20	32.7	4.3	40	25	519/10	31.9	7.5	34	14
	5	641/20	32.0	5.1	46	23					
16B-R	1	57/20	2.8	3.6	8	-6	11/10	1.1	2.9	6	-4
	2	88/20	4.4	4.1	13	-2	-6/10	-0.6	3.3	5	-6
	3	101/20	5.1	4.6	20	-1	30/10	3.0	3.8	10	-4
	4	232/20	11.6	4.2	21	4	41/10	4.1	3.5	8	-2
	5	308/20	15.4	4.5	22	8					
17A	1	150/13	11.5	2.4	16	8	106/8	13.2	2.3	18	10
	2	224/18	12.4	2.4	16	9	133/9	14.8	3.1	20	10
	3	244/16	15.2	2.3	20	13	155/10	15.5	2.8	20	10
	4	275/17	16.2	2.2	20	13	180/10	18.0	2.5	23	14
	5	298/16	18.6	2.9	24	13					
17B-B	1	353/20	17.6	3.2	26	12	197/10	19.7	1.1	22	18
	2	402/20	20.1	2.3	25	16	209/10	20.9	2.0	24	18
	3	436/20	21.8	2.5	26	17	223/10	22.3	1.6	25	20
	4	456/20	22.8	2.9	27	16	235/10	23.5	1.9	27	21
	5	507/20	25.4	3.4	33	21					
17B-R	1	165/20	8.2	1.5	13	6	122/10	12.2	1.2	17	9
	2	223/20	11.2	2.7	19	8	125/10	12.5	2.5	17	9
	3	197/20	9.8	2.4	15	6	127/10	12.7	1.9	17	10
	4	238/20	11.9	2.9	18	7	130/10	13.0	2.5	17	9
	5	199/20	10.0	2.6	15	5					

Subject: "p"

Data Sheet #1

		Squares:					Diamonds:				
					Range:					Range:	
Test	Target	Sum	Mean	Sigma	High	Low	Sum	Mean	Sigma	High	Low
13A	1	44/20	2.2	2.2	6	-2	45/10	4.5	1.5	6	1
	2	24/20	1.2	1.7	4	-2	33/10	3.3	1.1	5	1
	3	26/20	1.3	1.8	6	-1	28/10	2.8	1.7	5	0
	4	24/20	1.2	1.8	4	-4	42/10	4.2	1.3	6	2
	5	-13.5/20	-0.7	3.1	5½	-6					
16A	1	231/19	12.2	2.5	18	9	69/6	11.5	2.3	14	10
	2	285/20	14.3	1.9	18	10	104/8	13.0	2.7	18	10
	3	297/20	14.9	1.4	18	12	141/9	15.7	1.9	18	12
	4	385/20	19.2	3.4	29	14	172/10	17.2	3.3	18	13
	5	156/7	22.3	4.3	28	15					
16B-B	1	395/20	19.7	2.2	26	16	154/10	15.4	1.9	19	12
	2	437/20	21.9	2.4	26	20	179/10	17.9	2.9	23	14
	3	529/20	26.4	3.5	34	21	205/10	20.5	2.1	25	15
	4	669/20	33.4	3.6	40	26	287/10	28.7	2.3	33	26
	5	459/20	23.0	5.2	42	17					
16B-R	1	236/20	11.8	3.0	16	7	65/10	6.5	2.6	10	3
	2	288/20	14.4	2.8	18	10	78/10	7.8	2.5	13	5
	3	313/20	15.7	4.5	24	10	103/10	10.3	2.1	15	7
	4	400/20	20.0	3.6	26	11	126/10	12.6	2.9	19	9
	5	285/20	14.2	1.9	23	8					
17A	1	257/20	12.8	2.7	19	8	135/9	15.0	2.1	19	12
	2	255/19	13.4	2.6	18	10	147/10	14.7	3.3	21	11
	3	301/20	15.1	2.0	20	11	174/10	17.4	2.0	21	14
	4	322/20	16.1	1.6	21	13	170/10	17.0	2.4	22	14
	5	351/19	18.5	2.7	23	14					
17B-B	1	345/20	17.2	2.3	20	12	174/10	17.4	3.6	22	16
	2	371/20	18.6	2.0	22	14	198/10	19.8	1.8	22	17
	3	429/20	21.5	2.4	28	17	235/10	23.5	1.2	25	22
	4	484/20	24.2	2.4	29	18	258/10	25.8	2.0	28	21
	5	473/20	23.7	2.5	29	18					
17B-R	1	210/20	10.5	2.8	15	3	126/10	12.6	2.4	17	10
	2	219/20	11.0	2.6	15	5	124/10	12.4	2.9	15	6
	3	267/20	13.3	2.9	18	6	146/10	14.6	2.8	18	10
	4	337/20	16.9	5.0	22	8	126/10	12.6	3.1	16	7
	5	313/20	15.7	2.3	21	8					

Subject: "K"

Data Sheet #2

		Squares:					Diamonds:				
					Range:					Range:	
Test	Target	Sum	Mean	Sigma	High	Low	Sum	Mean	Sigma	High	Low
13A	1	32/20	1.6	6.0	12	-9	-70/10	-7.0	2.5	0	-12
	2	19/20	0.9	6.3	13	-7	-67/10	-6.7	1.2	-4	-8
	3	56/20	2.8	4.9	12	-6	-77/10	-7.7	3.4	-4	-12
	4	79/20	4.0	4.0	11	-6	-66/10	-6.6	2.1	-3	-10
	5	139/20	7.0	3.6	12	0					
16A	1	361/15	24.1	5.0	33	16	252/9	28.0	2.3	32	24
	2	417/17	24.5	4.8	33	16	298/10	29.8	4.8	42	24
	3	361/14	25.8	3.8	37	22	299/10	29.9	3.3	35	24
	4	371/14	26.5	6.5	39	14	317/10	31.7	3.0	36	27
	5	92/3	30.7	1.8	32	28					
16B-B	1	563/20	28.2	4.0	36	20	392/10	39.2	2.5	44	36
	2	603/20	30.2	4.8	36	19	407/10	40.7	2.4	43	34
	3	670/20	33.5	4.9	40	25	404/10	40.4	2.1	42	35
	4	688/20	34.4	5.2	42	26	418/10	41.8	1.9	44	38
	5	653/20	32.6	3.8	40	24					
16B-F	1	365/20	18.2	4.8	26	2	251/10	25.1	3.7	30	18
	2	383/20	19.2	5.3	28	9	278/10	27.8	3.7	38	21
	3	421/20	21.0	4.1	29	15	283/10	28.3	2.7	32	24
	4	452/20	22.6	4.2	28	16	291/10	29.1	2.8	44	38
	5	447/20	22.4	5.5	35	10					
17A	1	229/18	12.7	2.8	18	9	113/10	11.3	2.8	18	9
	2	227/19	12.0	1.8	15	8	108/10	10.8	3.0	14	8
	3	276/20	13.8	2.2	18	10	111/10	11.1	2.3	14	6
	4	301/20	15.0	2.9	19	9	127/10	12.7	2.1	16	8
	5	355/20	17.8	2.3	22	12					
17B-B	1	397/20	19.8	4.2	26	8	244/10	24.4	1.8	27	21
	2	431/20	21.6	3.6	25	12	247/10	24.7	2.3	28	20
	3	522/20	26.1	1.5	29	23	262/10	26.2	0.6	27	25
	4	532/20	26.6	2.1	32	22	269/10	26.9	1.9	30	23
	5	588/20	29.4	1.8	32	25					
17B-R	1	228/20	11.4	3.6	18	6	148/10	14.8	3.2	18	7
	2	280/20	14.0	3.3	19	7	157/10	15.7	3.6	20	8
	3	274/20	13.7	3.9	20	5	180/10	18.0	1.8	20	16
	4	311/20	15.6	3.7	20	13	178/10	17.8	2.0	21	15
	5	333/20	16.7	2.6	22	11					

Subject: "C"

Data Sheet #3

		Squares:			Range:		Diamonds:			Range:	
Test	Target	Sum	Mean	Sigma	High	Low	Sum	Mean	Sigma	High	Low
13A	1	78/20	3.9	3.2	8	0	58/10	5.8	2.8	10	1
	2	109/20	5.4	2.8	8	1	55/10	5.5	2.1	8	2
	3	102/20	5.1	2.7	8	2	40/10	4.0	2.4	8	1
	4	96/20	4.8	2.6	8	1	42/10	4.2	2.7	8	0
16A	1	136/12	11.3	4.2	21	5	88/8	11.0	1.9	14	9
	2	252/12	12.7	5.1	26	7	106/8	13.2	2.2	17	9
	3	213/15	14.2	3.6	20	8	118/7	16.9	4.4	26	10
	4	224/12	18.7	3.8	27	14	151/10	15.1	3.1	20	10
16B-B	1	364/20	18.2	3.3	26	11	177/10	17.7	4.7	24	10
	2	387/20	19.4	3.5	27	14	180/10	18.0	5.1	25	14
	3	387/20	19.4	4.2	28	12	215/10	21.5	4.5	26	13
	4	418/20	20.9	3.8	27	12	207/10	20.7	4.8	28	13
16B-R	1	143/20	7.2	5.8	17	-4	73/10	7.3	5.1	16	1
	2	136/20	6.8	4.0	12	0	99/10	9.9	5.6	20	2
	3	135/20	6.8	4.1	16	1	89/10	8.9	6.1	17	-3
	4	193/20	9.6	3.7	16	2	65/10	6.5	5.4	17	-4
17A	1	149/16	9.3	2.4	15	6	87/10	8.7	1.3	12	7
	2	193/19	10.2	3.0	16	6	97/10	9.7	1.4	12	8
	3	219/19	11.5	3.7	20	5	95/10	9.5	1.6	12	6
	4	254/19	13.4	3.0	18	9	90/10	9.0	0.9	11	8
17B-B	1	381/20	19.0	3.5	23	11	186/10	18.6	2.9	25	16
	2	395/20	19.8	2.5	24	15	195/10	19.5	1.9	24	17
	3	460/20	23.0	2.5	26	17	235/10	23.5	1.9	27	21
	4	537/20	26.8	2.5	33	20	289/10	28.9	1.1	31	27
17B-R	1	116/20	5.8	1.9	9	0	92/10	9.2	2.1	14	7
	2	164/20	8.2	2.8	13	2	84/10	8.4	2.3	12	4
	3	177/20	8.8	2.5	16	4	94/10	9.4	3.4	16	4
	4	204/20	10.2	3.2	16	2	111/10	11.1	1.9	14	8

Subject : "G"

Data Sheet #4

Standard Measurements Using

Reduced Snellen Letters For a Target

Test Subject		Sum	Mean	Sigma	Range: High	Low
13A	"P"	35/10	3.5	1.5	6	1
16A		165/8	20.6	2.6	23	14
16B-B		268/10	26.8	4.1	32	21
16B-R		90/10	9.0	4.2	15	3
17A		146/10	14.6	2.8	20	10
17B-B		234/10	23.4	1.8	26	20
17B-R		80/10	8.0	2.4	14	5
13A	"K"	41/10	4.1	1.0	6	3
16A		155/10	15.5	1.8	18	12
16B-B		250/10	25.0	2.4	30	23
16B-R		139/10	13.9	2.6	17	9
17A		175/10	17.5	2.6	21	12
17B-B		267/10	26.7	1.8	30	24
17B-R		142/10	14.2	2.0	17	11
13A	"C"	53/10	-5.3	1.6	-2	-8
16A		253/10	25.3	2.6	31	22
16B-B		421/10	42.1	2.2	46	39
16B-R		251/10	25.1	2.6	28	19
17A		122/10	12.2	2.6	16	8
17B-B		279/10	27.9	1.5	30	26
17B-R		131/10	13.1	3.2	17	8
13A	"O"	76/10	7.6	1.6	10	6
16A		124/10	12.4	3.0	18	8
16B-B		152/10	15.2	3.3	22	10
16B-R		71/10	7.1	3.7	14	2
17A		90/10	9.0	1.9	12	6
17B-B		258/10	25.8	1.8	29	24
17B-R		85/10	8.5	1.0	10	7

Data Sheet #5

The Amount of Change

For Each Target For Each Subject

Table #1: Squares:

Test:	Subject: "P"	"K"	"C"	"G"	Subject Mean
16A	1.6	2.0	1.7	2.5	2.0
16B-B	2.4	4.6	2.3	0.8	2.5
16B-R	2.8	2.5	1.5	0.7	1.9
17A	1.6	1.4	1.3	1.2	1.4
17B-B	1.7	2.0	2.4	2.6	2.2
17B-R	0.5	1.8	1.2	1.5	1.3
Test Mean	1.8	2.4	1.7	1.6	1.9*

Table #2: Diamonds:

Test:	Subject: "P"	"K"	"C"	"G"	Subject Mean
16A	1.5	1.9	1.2	1.3	1.5
16B-B	2.8	4.4	0.9	0.8	2.2
16B-R	1.0	2.0	1.6	-0.3	1.2
17A	1.9	0.7	0.4	0.1	0.8
17B-B	1.3	2.8	0.8	3.5	2.1
17B-R	0.3	0.0	1.0	0.6	0.5
Test Mean	2.0	1.5	1.0	1.1	1.4*

*Mean prism diopter change per increase in one log unit of target area.

Data Sheet #6

The Slopes

For The Square Targets

Subject: Test:	"K"	"P"	"C"	"G"
16A	0.51	0.64	0.61	0.41
16B-B	0.22	0.41	0.44	1.2
16B-R	0.40	0.34	0.68	curve
17A	0.73	0.62	curve	0.81
17B-B	0.51	0.59	0.42	curve
17B-R	0.55	2.0	0.85	0.68

The Slopes

For The Diamond Targets

Subject: Test:	"K"	"P"	"C"	"G"
16A	0.53	0.68	0.81	curve
16B-B	0.23	0.36	1.2	1.3
16B-R	0.51	curve	0.61	curve
17A	1.5	0.63	curve	curve
17B-B	0.32	0.79	1.2	curve
17B-R	none*	3.8	1.0	curve

*infinity

Data Sheet #7